AN INTENSE RAINSTORM AT FREMONT, MISSOURI, JULY 28–29, 1964

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ABSTRACT

An intense rainstorm at Fremont, Mo., on July 28, 1964, yielded over 3 in. of rain in 30 min. and a total of 9.5 in. in 5 hr. The synoptic weather situation which was responsible for producing such an intense rain is discussed. Mass rainfall curves, a total storm isohyetal map, an area-depth curve, and a graph of rainfall rates, are presented. Computed updrafts in the clouds versus observed updrafts from radar data are discussed; the maximum cloud penetration height is compared with observed radar echo heights.

1. INTRODUCTION

On a National Science Foundation grant to the University of Chicago, personnel of the Cloud Physics Laboratory have been studying the physics of precipitation in summer clouds over south-central Missouri. As an adjunct to a cloud seeding experiment, we installed 21 recording rain gages to supplement the rain gage network operated by the U.S. Weather Bureau.

A heavy rainfall occurred over a University of Chicago rain gage at Fremont, Mo., on July 28, 1964. The recording rain gage indicated that the storm rainfall began at 2120 CST and ended at 0220 CST. During the 5-hr. period the gage measured a total amount of 9.5 in. Although not a record storm for this area (see Lott [1]) this storm was remarkably intense and was observed by RHI radar which makes it worth recording in the literature.

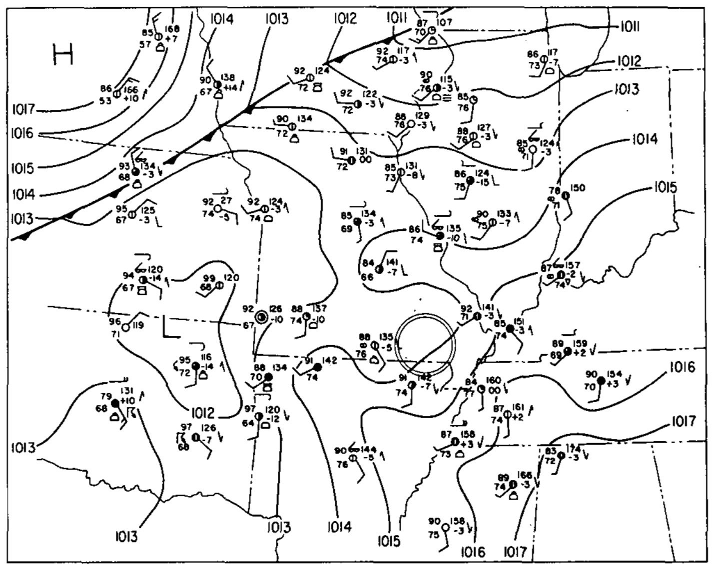

FIGURE 1.—Surface weather map for 1800 CST July 28, 1964. The circle in southeastern Missouri indicates the area where the heavy rain formed.

2. SYNOPTIC CONDITIONS

The surface weather map for 1800 CST of July 28, 1964, figure 1, shows a cold front extending from Wisconsin to the northwestern tip of Missouri and thence into eastern Colorado. The front was moving southeastward toward a low-level flow of humid southerly winds. The isobaric pattern indicated a micro-trough situated throughout the region of the Ozarks with surface level dew points between 66° and 76°F., and air temperatures around the mid 80's and lower 90's. The afternoon maximum temperatures exceeded 90°F. throughout the storm area. The storms leading to the heavy rain formed about 1900 CST in the micro-trough region and proceeded to move slowly toward the southeast with a speed of 8 kt.

By 2200 CST, after the period of most intense rain, the micro-trough had been replaced by a thunderstorm High (fig. 2). Otherwise the broad-scale synoptic features were unaltered.

The upper-air synoptic charts (figs. 3 and 4) show that the storm developed along a trough line at 850 and 700 mb. where there was marked convergence between light mP flow from the northwest and mT air from the south-

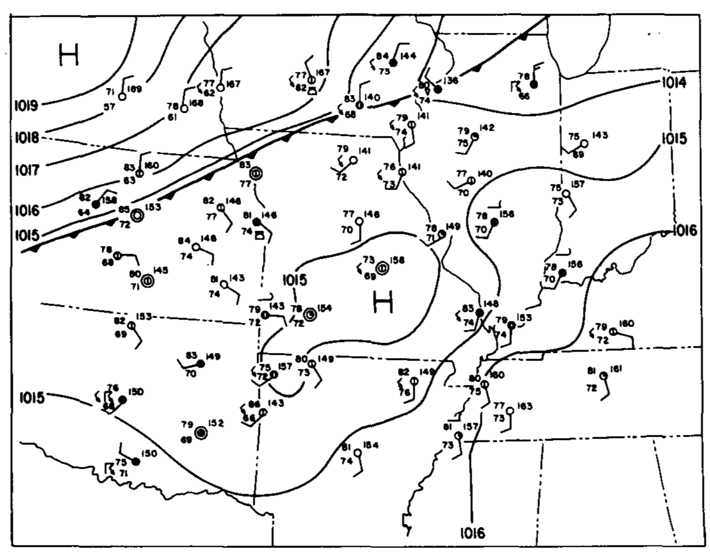

FIGURE 2.—Surface weather map for 2200 CST July 28, 1964, after the period of most intense rain.

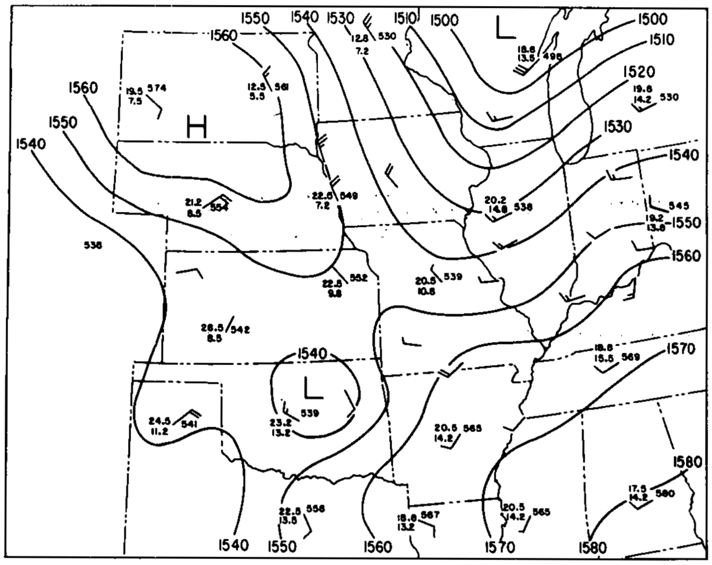

FIGURE 3.—850-mb. contours (meters) for 1800 CST July 28, 1964.

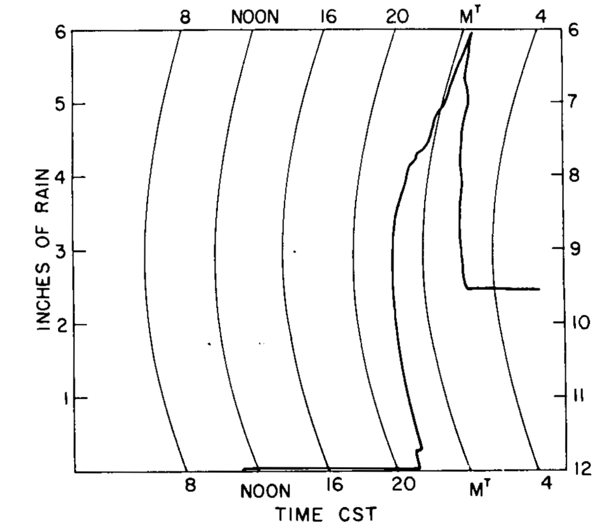

FIGURE 5.—Copy of recording rain gage trace for Fremont, Mo., 0800 CST July 28, 1964, to 0400 CST July 29, 1964.

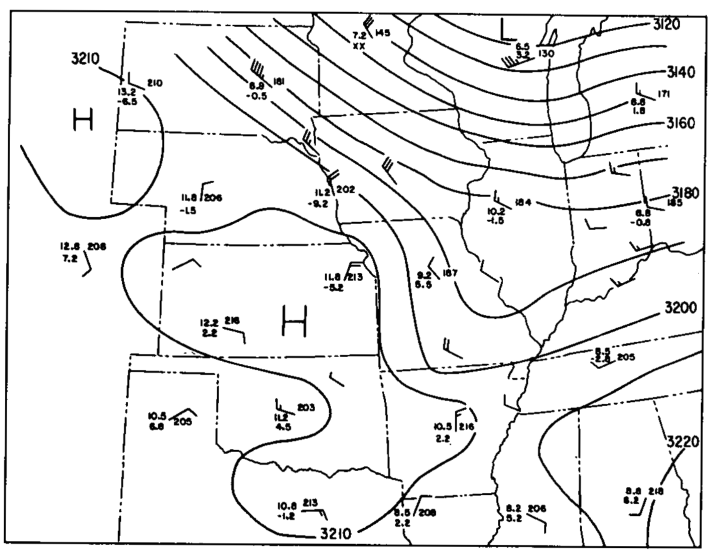

FIGURE 4.—700-mb. contours (meters) for 1800 CST July 28, 1964.

west. At 500 mb. the storm area was on the back side of a weak, broad trough centered in the Great Lakes area. The map of precipitable water from the surface up to the 400-mb. level showed values of 1.6 to 1.7 in. in the storm area, increasing toward the southeast to a value over 2 in. in Alabama and Mississippi. The closest sounding upwind of the storm, Columbia, Mo., showed that the moisture was principally limited to the levels below 700 mb.

Upper winds, both at Columbia and Little Rock at 1800 CST, were dry westerlies between 260° and 350° with moderate speeds of 7–20 kt., and with no marked shear.

3. STORM RAINFALL

Interest in this particular storm stems from the heavy rain which fell at Fremont and nearby stations. The rain gage record for Fremont is given in figure 5. Mass rainfall curves for Fremont and five other nearby recording rain gages are shown in figure 6. The maximum 30-min. rain amount was 3.07 in.; the maximum 1-hr. amount was 3.82 in. Based upon climatological data available to Hershfield [2] such large rain amounts would be expected to occur less than once every 100 yr. The rainfall rates were computed from the record at Fremont for each 15-min. interval (fig. 7). We note that the large rain total at Fremont came from three distinct bursts, probably representing three individual thunderstorm cells. The first of these gave a rate of rain of 7 in. hr.$^{-1}$ (15-min. average); the later two had half the magnitude of the first.

The total-storm isohyetal map, with its maximum values around Fremont, Mo., is shown in figure 8. The times of rainfall beginning and ending as shown by the recording gages, plus knowledge of the radar echoes and their movement, were used in the analysis of this chart. Note the orientation of the isohyetal pattern; the area of precipitation advanced from the northwest to the southeast with time. The area-depth curve for the total storm is given in figure 9. For a description of this procedure see Foster [3].

4. RADAR OBSERVATIONS

Radar data on the storm, from a TPS–10, 3-cm. height-finder radar located 12 mi. east of West Plains, are available up until 2240 CST, July 28, 1964. By 1900 CST the radar observations showed a group of well-developed echoes, roughly aligned east-west, located approximately 35 mi. north of Fremont. The echoes moved southeastward (140°) and intensified, and by 2000 CST echo tops had reached heights of 53,000 to 56,000 ft. (m.s.l.). The tropopause was located at 50,200 ft. Throughout this time the radar echoes were nearly vertical, reflecting the

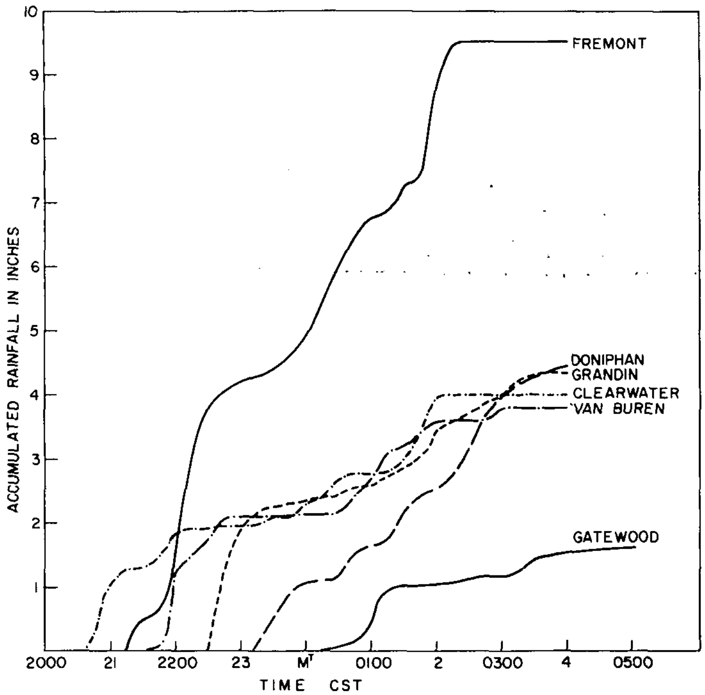

FIGURE 6.—Mass rainfall curves for six stations in southeastern Missouri for storm of July 28–29, 1964.

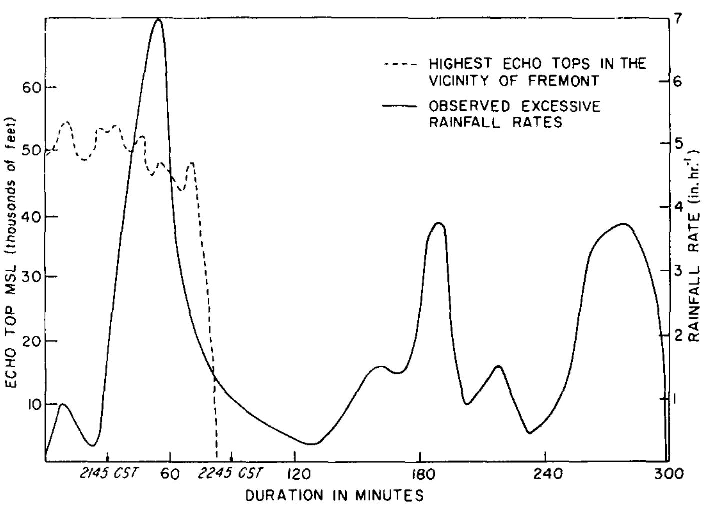

FIGURE 7.—Curve of rainfall rate (averaged over 15-min. intervals) and radar echo top heights.

limited shear in the environment winds. The strongest development of the line took place to the north of Fremont, over some of the hilliest parts of the northeastern Ozarks.

Heavy rainfall at Fremont began at 2120 CST. The radar indicates that the echoes became quasi-stationary at this time and about half of the heavy rain came from a single, nearly vertical, convective cell (fig. 7). Presumably the slow movement reflects the fact that the storm formed in the light winds at the confluence between the mT and mP air streams.

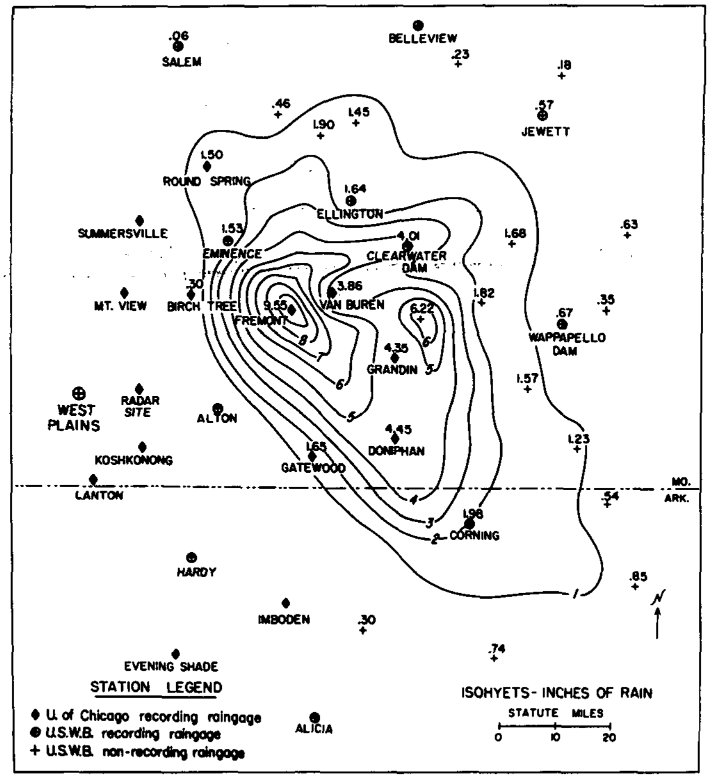

FIGURE 8.—Isohyetal map for storm at Fremont, Mo., July 28, 1964.

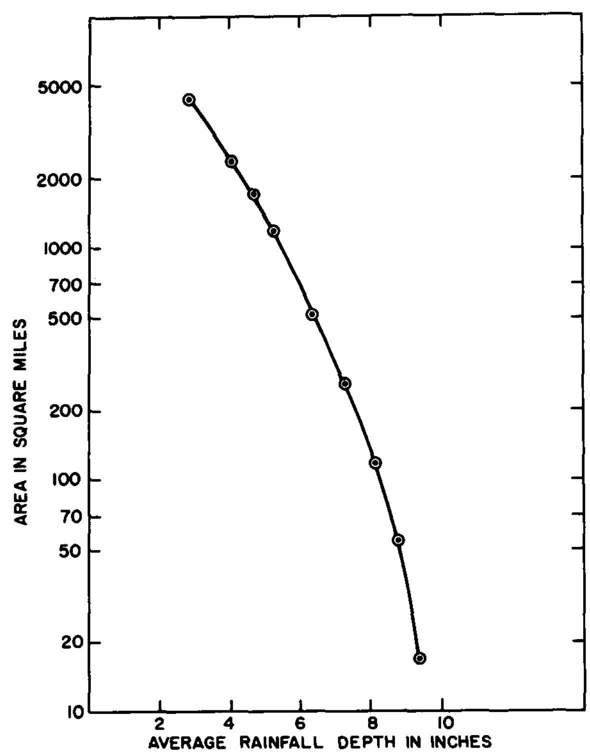

FIGURE 9.—Area-depth curve for the rainstorm of July 28, 1964.

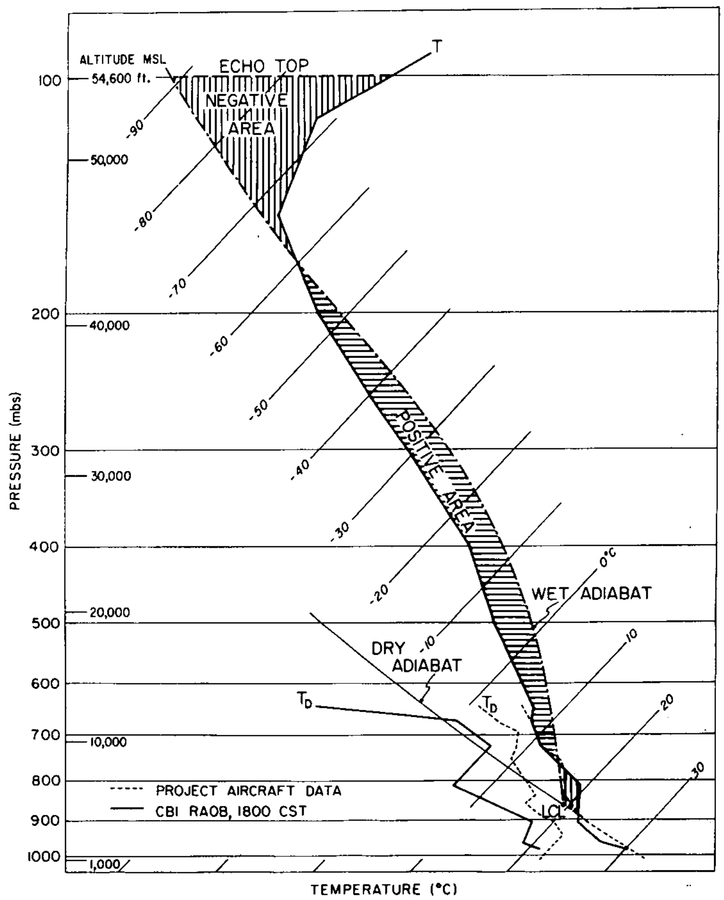

FIGURE 10.—Temperature and dew point sounding for pre-storm environment. Both Project aircraft data and 1800 CST, July 28, 1964, Columbia, Mo., sounding are shown. Parcel method positive and negative areas are shaded. Plotted on a Skew-T, Log P diagram.

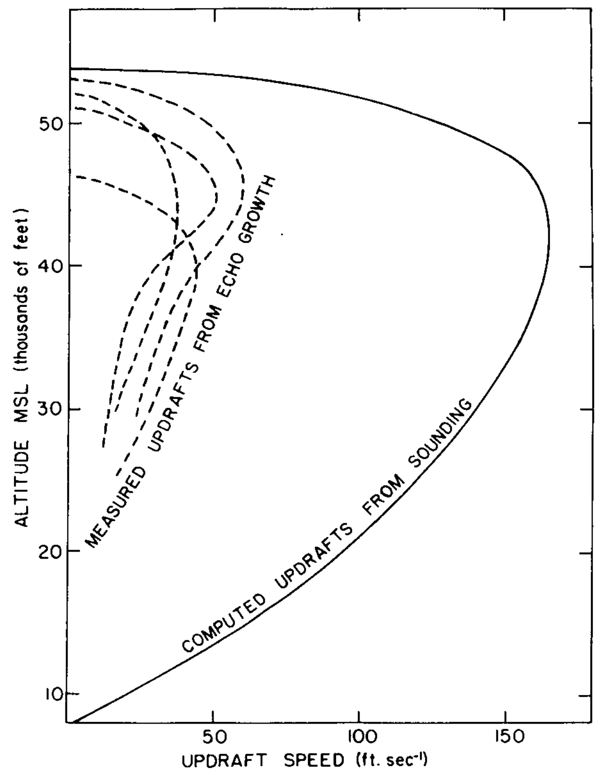

FIGURE 11.—Graph of measured updraft speeds (from rates of rise of radar echo tops) and computed updraft speed based upon a simple parcel-method approach.

An effort was made to use the radar data to help delineate the structure, development, and movement of these heavy precipitating clouds, but soon after the heavy rainfall began the radar beam was strongly attenuated by the wall of heavy rain, limiting the radar utility to echo tops.

5. SOUNDINGS AND COMPUTED VERTICAL VELOCITIES

The temperature and humidity conditions of the pre-storm environment are given in figure 10. Data up to 13,000 ft. are from the project aircraft which made a vertical sounding during the early afternoon. At that time heavy haze was reported over the whole area with visibility about 6 mi. The Columbia, Mo., 1800 CST raob has been chosen as representative of the conditions above 13,000 ft. since it best represents the air mass in which the storm developed (in view of the upper winds and direction of storm movement). The lifting condensation level in the pre-storm sounding is 860 mb. or 5,200 ft. (m.s.l.) which is in general agreement with observed cloud bases throughout the area. The sounding shows conditional instability with all the moist air below 670 mb.

It is interesting to compare the measured radar top heights with those computed assuming a parcel method ascent from the cloud base. The maximum heights of echoes in the vicinity of Fremont are shown in figure 7. The maximum height observed was 54,000 ft. This value is a little uncertain because of the finite beam width, but the uncertainty is only about $\pm 1{,}000$ ft. since the vertical beam width of the TPS–10 is 0.7 deg.

The use of the parcel method in such a compilation is hard to defend on grounds other than simplicity and that it seems to give useful answers. Entrainment as a factor affecting cumulus cloud growth is well known. It is possible, however, that in the cores of heavy thunderstorms very little environmental air is able to penetrate, with the result that they dilute very slowly. Vonnegut and Moore [4] used this premise in investigating giant thunderstorms which penetrated the stratosphere.

Figure 11 shows the magnitude of the vertical velocities computed using parcel buoyancy acceleration, neglecting drag and friction. The maximum computed updraft speed (165 ft. sec.$^{-1}$) was found at 180 mb. (43,000 ft.). Above that level it decreased in magnitude toward the upper negative area and reached zero speed at a height of

54,000 ft. On the left hand side of figure 11 are shown vertical velocities measured from echo top growth of four individual echo turrets which grew between 1957 and 2159 CST. The computed updraft maximum is about 2.5 times the ascent rate of the echo tops. This seems to be in keeping with theoretical and laboratory studies of the vortex ring model of cumulus clouds [5, 6]. This implies that the vortex models may have value in studies of turrets rising to the tops of giant storms, and gives promise that combination of theoretical and empirical studies may someday make it possible to predict storms like that which occurred on July 28, 1964.

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